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Specification

## SWITCHING CIRCUIT FOR AN ELECTROMAGNETIC SOURCE FOR THE GENERATION OF ACOUSTIC WAVES

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The invention concerns an electrical circuit for an electromagnetic source for the generation of acoustic waves.

One such electrical circuit according to the state of the art is depicted in Figure 1.  
10 the electrical circuit comprises an intermediate direct current link source 1, switching equipment 2, that is designed as a discharger as a rule, a condenser C as well as a coil L, that is part of the sound generating unit of the electromagnetic source. The sound generation unit for the electromagnetic source features a not depicted coil carrier next to coil L, upon which the coil is arranged, and an  
15 insulated membrane arranged on coil L (not depicted either). At the discharge of condenser C via coil L a current  $i$  flows through coil L, whereby an electromagnetic field is generated that appears with the membrane in interaction. The membrane is thus leveled out in an acoustic propagation medium, whereby source pressure waves are transmitted in the acoustic propagation medium as  
20 carrier medium between sound generating unit of the electromagnetic source and to a sound absorbing object. Shock waves can arise, for example via non-linear effects in the carrier medium of the acoustic source pressure waves. The composition of an electromagnetic source, especially of electromagnetic shock waves, is, for example specified in EP 0 133 665 B1.

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Shock waves are deployed, for example, for non-invasive destruction of concrements in the inner body of a patient, for instance for the destruction of kidney stones. The shock waves directed at the kidney stones affect kidney stones that cracks arise. The kidney stone breaks apart finally and can be separated out in  
30 natural fashion.

When one operates the electrical circuit for the generation of acoustic waves depicted in Figure 1, resulting during the discharge process of the condenser C via coil L, whereby a short circuit is generated through means of sound medium 2, recorded, for example as progress of current  $u(t)$  (curve 3) via the coil L and of  
5 current  $i(t)$  (curve 4) via coil L. the abating current  $i(t)$  that flows through coil 4 is, as mentioned already, causal for the generation of acoustic waves.

The acoustic waves generated by the electromagnetic shock wave source are proportional to the quadrant of current  $i(t)$ , curve 5 in Figure 2. an initial acoustic  
10 source pressure wave from the first acoustic source pressure pulse (1.maximum) and further acoustic source pressure waves from the abating cycle of positive acoustic source pressure pulse emanates forth from a discharge of condenser C. the first source pressure waves and the subsequent source pressure waves can form, as mentioned already, in shock waves with short positively (spiked) charged  
15 particles and subsequently long drawn-out so-called negative pressure troughs via non-linear effects in carrier medium and a non-linear focusing, which takes place as a rule with a known acoustic focusing lens.

Via the frequency of the current  $i(t)$  flowing through coil L, characteristics of the  
20 shock wave, such as its focal radius for example, can be altered. With a variable current frequency and thus a variable frequency of the shock wave, the size of the effective focus is changeable, for example, and adjustable according to use of the object to be handled. For instance, the effective focus of the lithotripter can be chosen according to the respective grain/pebble size, so that the acoustic energy is  
25 utilized better for the disintegration of the grain/pebble and the surrounding webbing burdened less.

A variable capacity of the condensor C and a variable inductivity of coil L are costly due to relatively high short circuit performance through the 100 MW region.  
30 To vary the shock wave, only the charge voltage of the condensor C is, thus varied generally, whereby the maxima of the current  $i(t)$  changes via the coil L and the

voltage  $u(t)$  to the coil  $L$ . the curve forms for the current  $i(t)$  and the voltage  $u(t)$  stay, however, essentially the same.

The invention forms thence a basis in the task, to develop an electrical circuit at  
5 entry of the named type, that the generation of acoustics waves is improved.

According to the invention this task is solved via an electrical circuit for an  
electromagnetic source for the generation of acoustic waves, identified hence, that  
an electrical circuit comprise at least one first condenser, that is connected in  
10 parallel to at least one serial circuit of a second condenser and on first closure  
element.

The first closure element, that according to a preferred embodiment of the  
invention is a first diode or a first diode module, is thus switched such that it  
15 blocks both condensers after charging, thus equalization processes between both  
condensers are impeded. The first condenser can, thereby be charged with a  
greater charge than the second condenser prior to the discharge of both condensers.  
first the discharge of the first condenser, thence the condenser with the greater  
charge must begin via the coil for the generation of acoustic waves. As soon as the  
20 charge of the first condenser, at least essentially, equals the charge of the second  
condenser, the first closure element becomes conductive, so that both condensers  
discharge. Consequently the electrical circuit has the capacity of the first  
condenser to discharge before the second condenser begins. While both  
condensers discharge, the electrical circuit has a capacity that equals the sum of  
25 capacities of both condensers. By a variation of the charge of both condensers the  
curve form for the electricity can be altered via the coil, whereby in turn the  
characteristics of the shock wave can be varied. The curve form of the discharge  
voltage can be varied further, if the electrical circuit features multiple, in series  
switchable closure elements/condenser pairs, that are switched parallel to the first  
30 condenser and are charged with different voltages.

The first diode module comprises incidentally, for example of a row- and/or parallel switch of multiple diodes.

Charging prior to the discharging of the first condenser with the first direct voltage  
5 source and the second condenser with a second direct voltage source according to  
an embodiment of the invention can occur. According to a preferred embodiment  
of the invention, it is designed to charge the first condenser and with second  
condenser with exactly one direct voltage source and to switch off the direct  
voltage source of the second condenser with switching equipment, as soon as the  
10 second condenser reaches its voltage. The switching equipment comprises at least  
one semiconductor according to an embodiment of the invention.

The parallel switch of the second condenser/first closure element and first  
condenser is switched parallel to a second closure element, that is designed  
15 according to an especially advantageous embodiment of the invention. The second  
closure element is according to an advantageous embodiment of the invention a  
second diode or a diode module. A timely extension of the first source pressure  
pulse is achieved at the discharging of the condensers via the parallel switch of the  
second closure element to the condensers. In addition the consequent abating  
20 source pressure pulse dependent upon the impedance of the second closure element  
is greatly absorbed. The absorption can be, thereby so great, that the consequent  
source pressure pulse entirely disappears. Via the timely extension for the first  
source pressure pulse, a stronger first acoustic wave, for example at the generation  
of shock waves, is generated, thus a stronger first shock wave generated, whereby  
25 an amplification of volume disintegrating effect results for the demolition of  
concretions. Tissue-damaging cavitation, caused by the first shockwaves  
consequent of the source pressure pulse's preceding shock waves are mitigated,  
thereby, that only few weak or even none of the first source pressure pulses or  
subsequent source pressure pulses occur. The life expectancy of the the first and  
30 the second condensers is, thus increased via the conditionally reduced, polarity  
reversing voltage via the second closure element. In addition at such a generation